Review Article

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History and Modalities of Forensic Radiology

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Abstract

Forensic Radiology is a specialized area of medical imaging utilizing radiological techniques to assist physicians & pathologists in matter pertaining to the law. It comprises the performance, interpretation and reportage of the radiological examinations and procedures which are needed in court procedures or law enforcement. Radiological methods are widely used in identification, age estimation and establishing cause of death. This article describes the history and modalities of forensic radiology.

Keywords: Forensic Radiology; Virtopsy; 3D; Imaging; MRI; Conventional.

Inroduction

The routine diagnostic imaging methods are used in forensic biomedical practice and research. Studies in the field have resulted in the establishment of forensic stan-dards, as in the fields of skeletal development and maturation. For example, laryngeal car-tilages undergo age changes, including mineralization and ossification, a recent study analysed the degree of laryngeal radiopacity to determine whether radiog-raphy of the larynx can be used routinely in forensic pathology to estimate age at death. The study found a positive correlation between the total score of laryn-geal radiopacity and age. It was concluded that radiological methods are simple, fast, non destructive, and has a good reproducibility among observers [1].

Rapid technical advances have occurred in radiology in so many years. Many of these new techniques and modalities have also been embraced and modified by the forensic science community. Examples include con-trast techniques for the study of cadaver arterial systems, the use of solidifying rubber with lead oxide in autopsy studies of vascular structures, and similar contrast tech-niques for demonstration of esophageal, tracheal, and aortic fistulae. As in clinical medicine, the usefulness of MRI and CT in forensic radiology has been demonstrated. For example, one study looked at the feasibility of circum-venting the classic forensic autopsy by replacing it with a full-body CT scan [2, 3, 4].

Complete volume data of the head, neck, and trunk were acquired using two acquisitions with less than one minute of total scanning time. Sophisticated reformation tech-niques helped document the gunshot-created skull frac-tures and brain injuries, including the wound track, and the intra cerebral bone fragments. CT also demonstrated intra cardiac air embolism and pulmonary aspiration of blood resulting from wound-related trauma. The study concluded that, the so-called digital autopsy, even when post processing time was added, was more rapid than the classic forensic autopsy and, based on the non destructive approach, offered certain advantages in comparison with the forensic autopsy [5].

Autopsy is the scientific examination of bodies after death, where whole surface of the body as well as all the body cavities are explored to record the findings. It is long back that the autopsy procedures were invented and till now the same age old techniques for autopsy are being used, though in the other fields of Forensic Medicine, there is rapid growth and advancement in the procedures performed and technology employed. Virtopsy is one step towards this end [6].

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The term "virtopsy" was created from the terms "virtual" and "autopsy." The former term is derived from the Latin word *virtus*, which means "useful, efficient, and good." The term "autopsy" is a combination of the classical Greek terms *autos* ("self") and *opsomei* ("I will see"). Thus, autopsy means "to see with one's own eyes." Because goal was to eliminate the subjectivity implied by *autos*, research merged the terms "virtual" and "autopsy"- deleting *autos*- to create the term "virtopsy" [2].

Virtopsy basically consists of *(a)* body volume documentation and analysis using CT, MR imaging, and microradiology; and *(b)* 3D body surface documentation using forensic photogrammetry and 3D optical scanning. The resulting data set contains high-resolution 3D colour-encoded documentation of the body surface and 3D volume documentation of the interior of the body. By manipulating the data set with volume-rendering (VR) tools at a workstation, one can perform a virtual autopsy anytime, in any place. No forensic findings are disturbed, as they would be by the destructive techniques used in traditional autopsy [8].

The Virtopsy or "virtual autopsy" was developed by Richard Dirnhofer, former Director of Forensic Medicine, Berne, which was then continued by his successor, Michel Thali and his colleagues at the University of Berne's Institute of Forensic Medicine, Switzerland. "If you are doing an autopsy, you are always destroying the 3-D geometry of the body," says Thali, the forensic pathologist and project manager for Virtopsy. "Using this cross-section imaging technique, it is possible to document the same findings in a non invasive way" [8].

The Imaging Techniques Applied in Virtopsy

Whenever a photograph is taken, it always gives a two dimensional view of the particular object. So, if a wound photograph is taken, it will give the position, as well as length and breadth of the wound but cannot display the depth of the wound. So for determination of the depth, a three dimensional view of the wound is essential to understand the actual dimensions. So, in Virtopsy, there is combination of the technologies of medical imaging techniques as well as other technologies used in other field of science. 3-D surface scan used in the automobile designing is used to map the exterior of the body. It gives and documents the three dimensional image of the body surface area in detail [8].

- Multi-slice computed tomography (MSCT) and
- Magnetic resonance imaging (MRI)–which visualizes the interior of the body for collection of all the data in details in regards of condition of different organs. One can examine the part of the body slice by slice in different planes according to the requirement of the situation [8].

Apart from these, using the magnetic resonance imaging spectroscopy, time since death can also be estimated by measuring metabolites in the brain, emerging during post-mortem decomposition. The samples for histopathological examination if required can be collected more precisely using CT guided needle biopsy. Postmortem angiography is used to visualise the cardiovascular system [3,4].

Michael Thali and colleagues at the University of Berne's Institute of Forensic Medicine, has studied in more than 100 autopsies in Switzerland and the findings of the Virtopsy procedure has matched almost perfectly in side by- side comparisons with those of the conventional autopsy procedures. The comparisons were checked for a number of forensically pertinent points such as detection of gas, fractures and foreign bodies, as well as tissue and organ trauma. When teamed with post-mortem angiography and biopsy procedures, Michael Thali says that there is little of forensic importance that the virtual autopsy cannot detect [2, 5].

The 'Surface scanner' is the means for measuring and depicting the images in three dimensional views with precision. The object is photographed from different angles using digital camera which is then fed in to a computer. The body is scanned from all sides using a sensor which takes pictures using two cameras. The computer then reproduces the image of the body in three dimensional views which can be rotated as per requirement without any distortion for collection of the findings [8].

In the initial period, In Virtopsy, researchers use only the CT and the MRI for detection of the findings; but in that method, there were limitations as the images formed were only in grayscale, and so many findings were difficult to appreciate. But the new combined method of 3-D/CAD-supported photogrammetry and the medical imaging technique like the MSCT, MRI etc., give a much better result. Using this merging method of coloured photogrammetric surface scan and gray-scale radiological internal documentation, a great step towards a new kind of reality-based, high-tech wound documentation and visualization in forensic medicine is made. The combination of the methods of 3D/CAD Photogrammetry and Radiology has the advantage of being observer-independent, non-subjective, non-invasive, digitally storable over years or decades and even transferable over the web for second opinion. Moreover, by using this method, matching of the weapon of offense or the offending object with the wound can be made [9].

Using the post-mortem angiography, the whole cardiovascular system can be visualised. If there is any injury to a vessel, there will be spillage of the dye to the surrounding tissues, making it visible in the CT images. So, minute injuries to the blood vessels even to a capillary also can be detected in this method which is usually missed in the conventional autopsy. Apart from that, it is not possible to determine the findings in the heart muscles immediately after an ischemic attack, and so using this technique, the coronary vessels can be better assessed for any occlusion etc. than in case of the conventional autopsy [9].

Application of Minimally Invasive Techniques

To allow tissue specimens to be obtained for histologic analysis, a minimally invasive, radiological imaging guided biopsy technique was implemented for forensic use in corpses. This technique makes it possible to obtain not only tissue specimens but also samples of urine, bile, or blood for toxicologic or DNA investigations [4].

Application of Micro Radiologic Techniques

Emerging technologies such as high-resolution CT (micro-CT) and MR microscopy (micro– MR imaging) provide images with high spatial resolution [2]. With sub millimeter resolution, MR microscopy is a promising technique in the study of injury patterns in soft tissues [5]. MR microscopy can be used to analyze electrical injury patterns on human skin or to document specific ophthalmologic findings that might indicate shaken baby syndrome when the circumstances exclude an alternative explanation [10]. Micro-CT and micro– MR imaging might be used to perform microvirtopsy on forensic tissue specimens prior to destructive sectioning [10].

With the help of advanced graphic software, 3D data sets collected from intact specimens can be post processed to show different views (multiplanar reformatted images, 3D displays), digitally isolate (segment) 3D structures, and quantify volumes and surface areas for morphometry [10].

3D Colour-Encoded Surface Scanning

Skin and bone injuries are 3D. With conventional documentation methods like photography, 3D objects are unfortunately displayed in only two dimensions, which can sometimes be insufficient for forensic and scientific analysis. The forensic application of the TRITOP / ATOS II system (GOM) consists of 3D documentation of the formed injury on the body (skin, bone) and of the weapon (injury-causing instrument) that was presumably used [11].

The suspected weapon can be documented three dimensionally in the same way. Both 3D models are real data– based, and their sizes and dimensions are calibrated. Subsequently, the use of the suspected weapon can be confirmed or excluded on the basis of the correspondence between the weapon and the formed injury. Thus, a weapon that turns up months or even years after autopsy has been performed can be linked to patterned injuries on the body. After the weapon is scanned, attempts at correlation are made in a virtual 3D space. Possible morphologic correlations range from that between small bite wounds and the dentition of possible offenders to that between patterned injuries on the body of a traffic accident victim and the possible involved vehicle [11].

Fusion of Cross-Sectional and 3D Surface Scanning Data

In preparation for the fusion of surface and cross-sectional volume data sets, additional “radiologic landmarks” (multi-modality markers for CT or MR imaging) can be placed on the dead bodies [10,11]. The merging or fusion process is actually carried out with specific 3D software programs. To date, various research groups has validated the following methods of fully merging surface data sets with radiologic internal body data sets in 3D: [10,11]

1. The photogrammetric data set for a smaller injury can be merged with the radiologic 3D reconstructed image of the skin or soft tissue. Visible radiologic landmarks are useful for correlating the data sets. If the wound is located in an anatomically stable region, a fusion process based on geometric anatomic fusion is possible even without radiologic markers [10,11].
2. The 3D optical surface scan, acquired with the TRITOP / ATOS II system (GOM), can be matched (merged) with the radiologic data set. This new approach holds promise for the analysis of large, widespread, or complex injuries on the body surface or for cases in which whole-body documentation is necessary [10,11].

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